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Holowick

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(45) **Date of Patent:** **Mar. 23, 2004**

(54) **RADIO FREQUENCY AUTOMATED METER READING DEVICE**

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(73) Assignee: **Datamatic Inc.**, Plano, TX (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **09/419,743**

(22) Filed: **Oct. 16, 1999**

(51) **Int. Cl.**^{7} **G08B 23/00**
(52) **U.S. Cl.** **340/870.02**; 340/870.07; 375/220; 702/62
(58) **Field of Search** 340/870.02, 870.03, 340/870.06, 870.07, 870.11; 375/220; 702/61, 62

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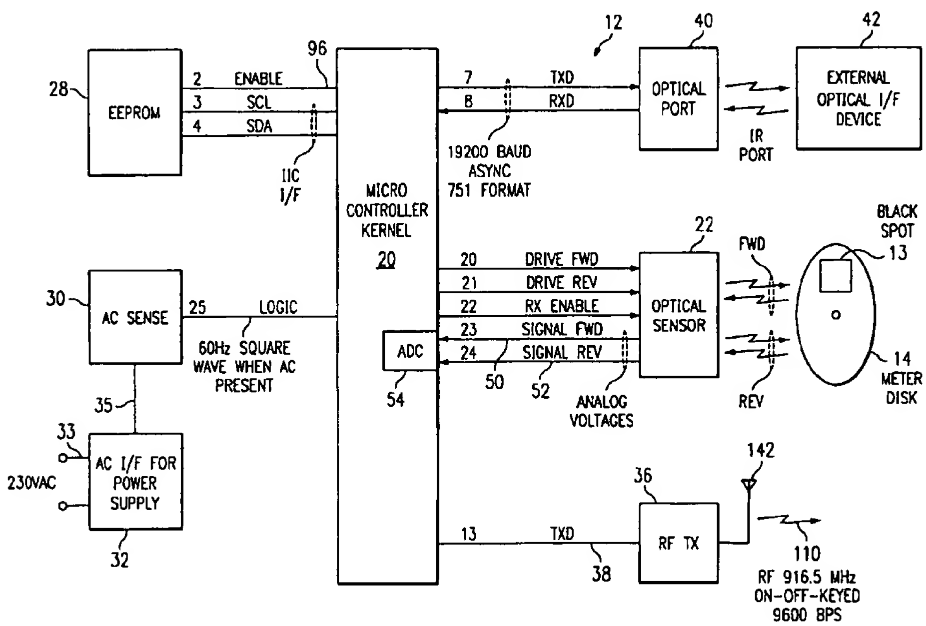
Primary Examiner—Albert K. Wong
(74) *Attorney, Agent, or Firm*—Robert C Klinger; Jackson Walker LLP

(57) **ABSTRACT**

A radio frequency automated meter reading (AMR) device for determining quantities of a consumed utility product including electric, gas and water service. The present invention intermittently transmits utility product consumption as a modulated RF signal, and does not require complex polling and bi-directional communication. Data is obtained and formatted for transmission and is adapted to be received by a remote receiving device having an RF receiver. The present invention is adaptable to water meters, gas meters and electric meters, and has an IR programming module facilitating remote programming and diagnostic procedures. In the case of water and gas meters, an internal lithium battery provides an operational life of up to ten years. In the case of the electric meter, power is tapped directly from the electric service.

13 Claims, 17 Drawing Sheets



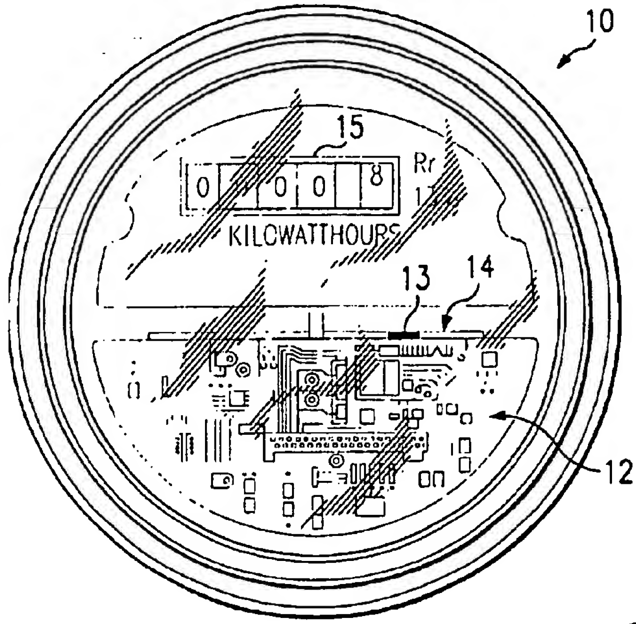


FIG. 1

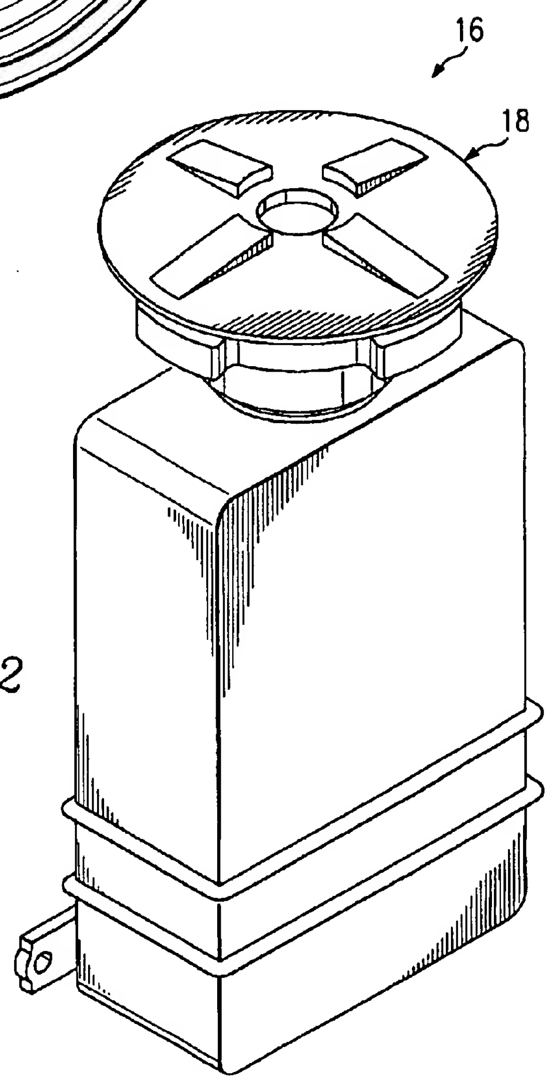
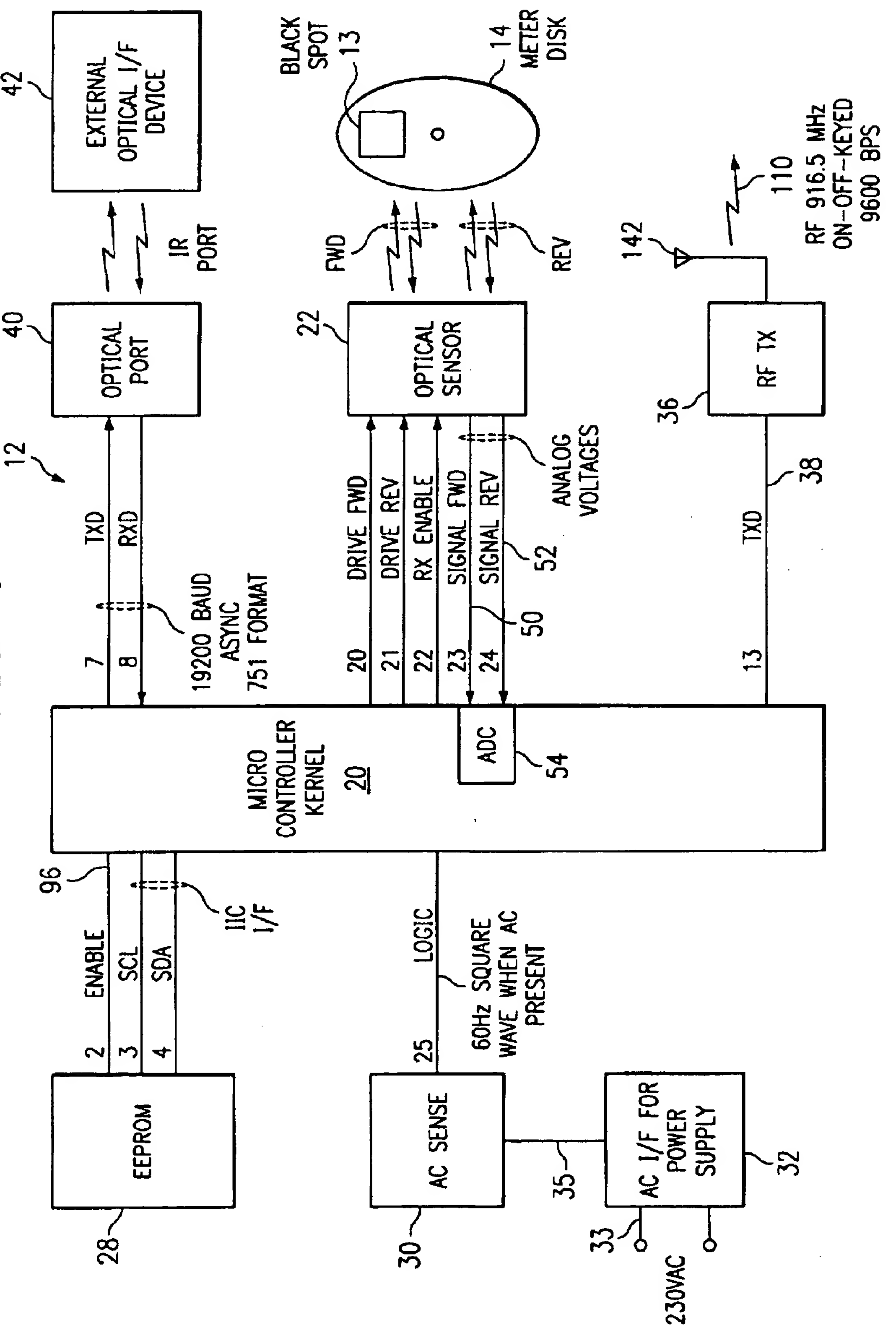


FIG. 2

FIG. 3


12
EXTERNAL OPTICAL I/F DEVICE
42
IR PORT
OPTICAL PORT
40
TXD
RXD
7
8
19200 BAUD ASYNC 751 FORMAT
BLACK SPOT
13
14
METER DISK
FWD
REV
OPTICAL SENSOR
22
DRIVE FWD
DRIVE REV
RX ENABLE
SIGNAL FWD
SIGNAL REV
20
21
22
23
24
ANALOG VOLTAGES
52
50
RF 916.5 MHz ON-OFF-KEYED 9600 BPS
110
142
RF TX
36
TXD
38
13
MICRO CONTROLLER KERNEL
20
ADC
54
96
ENABLE
SCL
SDA
2
3
4
IIC I/F
EEPROM
28
LOGIC
25
60Hz SQUARE WAVE WHEN AC PRESENT
AC SENSE
30
35
AC I/F FOR POWER SUPPLY
32
33
230VAC

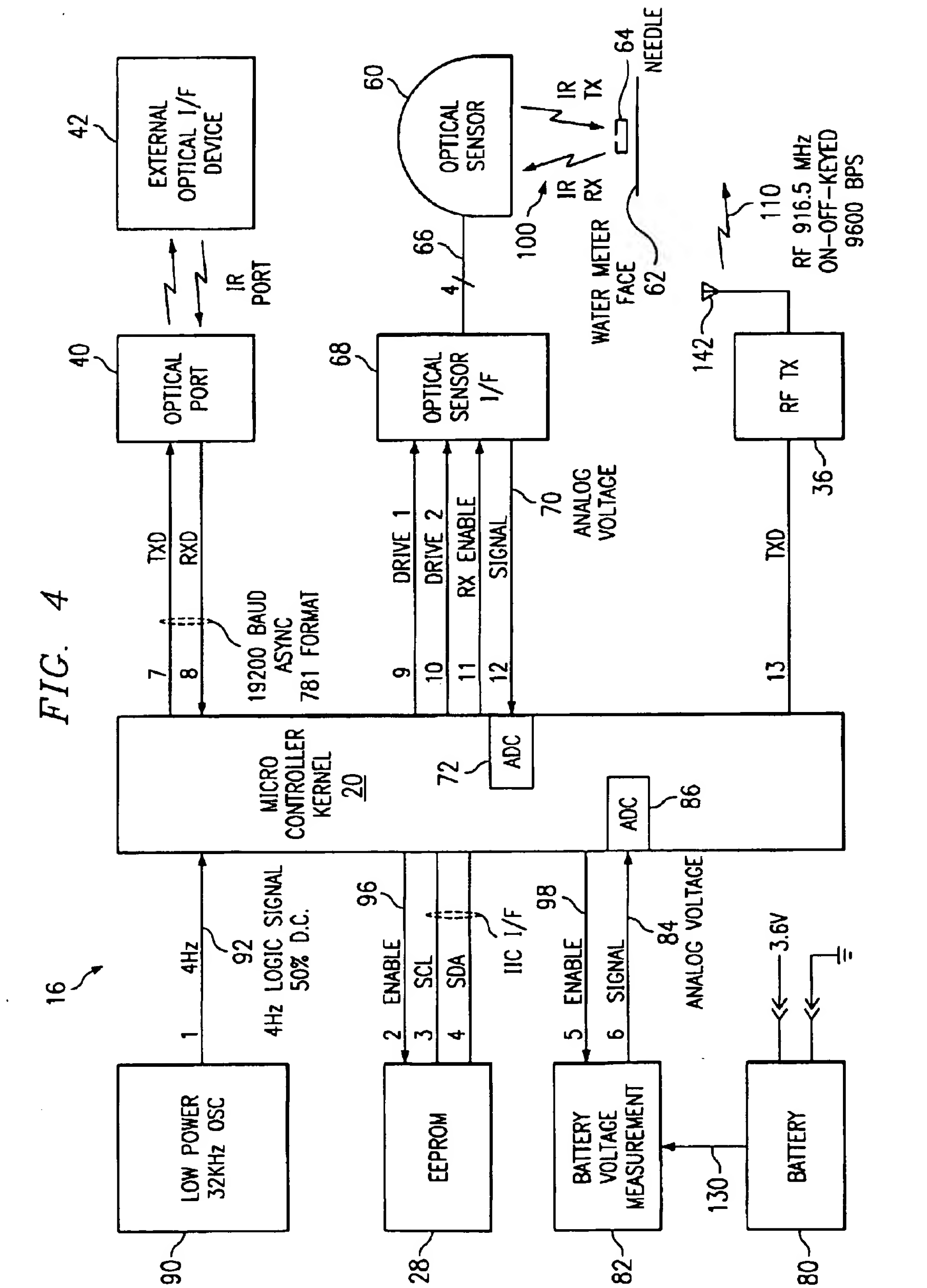

16
LOW POWER 32KHz OSC
90
1 4Hz
92
4Hz LOGIC SIGNAL 50% D.C.
EEPROM
28
2 ENABLE
3 SCL
4 SDA
96
IIC I/F
BATTERY VOLTAGE MEASUREMENT
82
5 ENABLE
6 SIGNAL
98
84
ANALOG VOLTAGE
BATTERY
80
130
3.6V
MICRO CONTROLLER KERNEL 20
ADC
72
ADC
86
7 TXD
8 RXD
19200 BAUD ASYNC 781 FORMAT
OPTICAL PORT
40
IR PORT
EXTERNAL OPTICAL I/F DEVICE
42
9 DRIVE 1
10 DRIVE 2
11 RX ENABLE
12 SIGNAL
70
ANALOG VOLTAGE
OPTICAL SENSOR I/F
68
66
4
OPTICAL SENSOR
60
IR RX
IR TX
100
64
NEEDLE
WATER METER FACE
62
13 TXD
RF TX
36
142
110
RF 916.5 MHz ON-OFF-KEYED 9600 BPS

FIG. 4

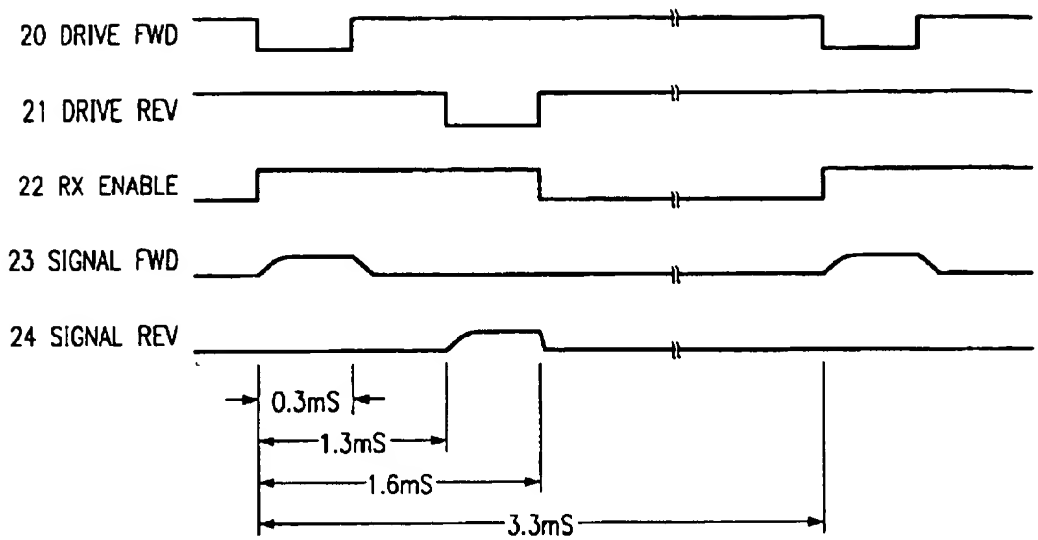

20 DRIVE FWD
21 DRIVE REV
22 RX ENABLE
23 SIGNAL FWD
24 SIGNAL REV
0.3mS
1.3mS
1.6mS
3.3mS

FIG. 5

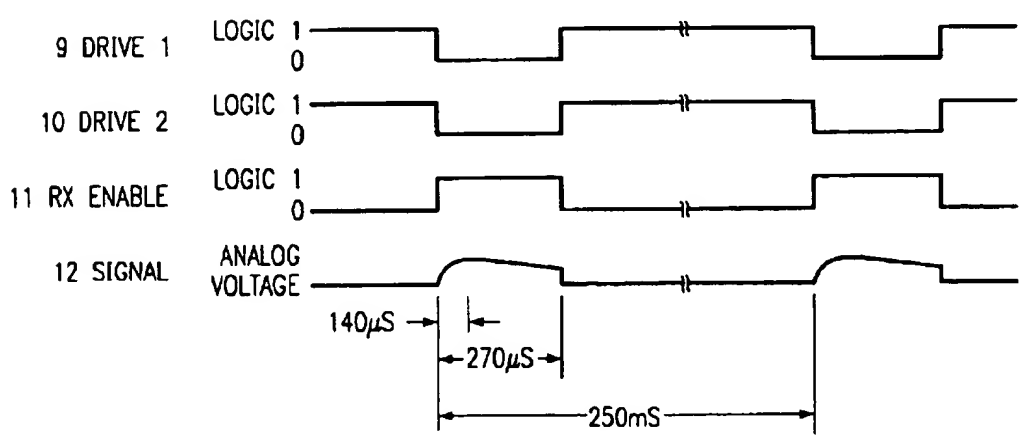

9 DRIVE 1
LOGIC 1
0
10 DRIVE 2
LOGIC 1
0
11 RX ENABLE
LOGIC 1
0
12 SIGNAL
ANALOG VOLTAGE
140μS
270μS
250mS

FIG. 6

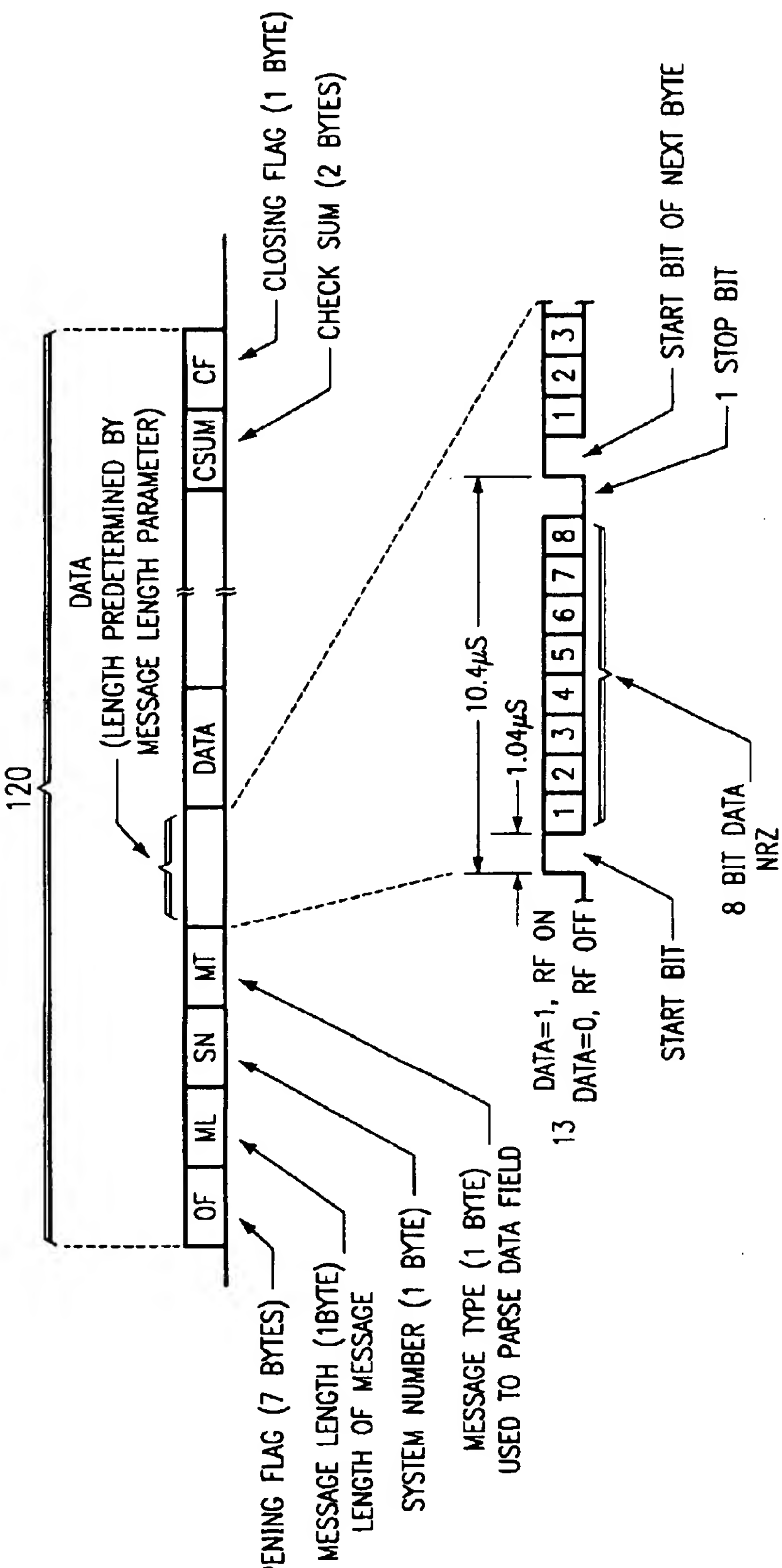

120
OF
ML
SN
MT
DATA
CSUM
CF
DATA
(LENGTH PREDETERMINED BY
MESSAGE LENGTH PARAMETER)
OPENING FLAG (7 BYTES)
MESSAGE LENGTH (1BYTE)
LENGTH OF MESSAGE
SYSTEM NUMBER (1 BYTE)
MESSAGE TYPE (1 BYTE)
USED TO PARSE DATA FIELD
CLOSING FLAG (1 BYTE)
CHECK SUM (2 BYTES)
10.4μS
1.04μS
1 2 3 4 5 6 7 8
1 2 3
13
DATA=1, RF ON
DATA=0, RF OFF
START BIT
8 BIT DATA
NRZ
1 STOP BIT
START BIT OF NEXT BYTE

FIG. 7

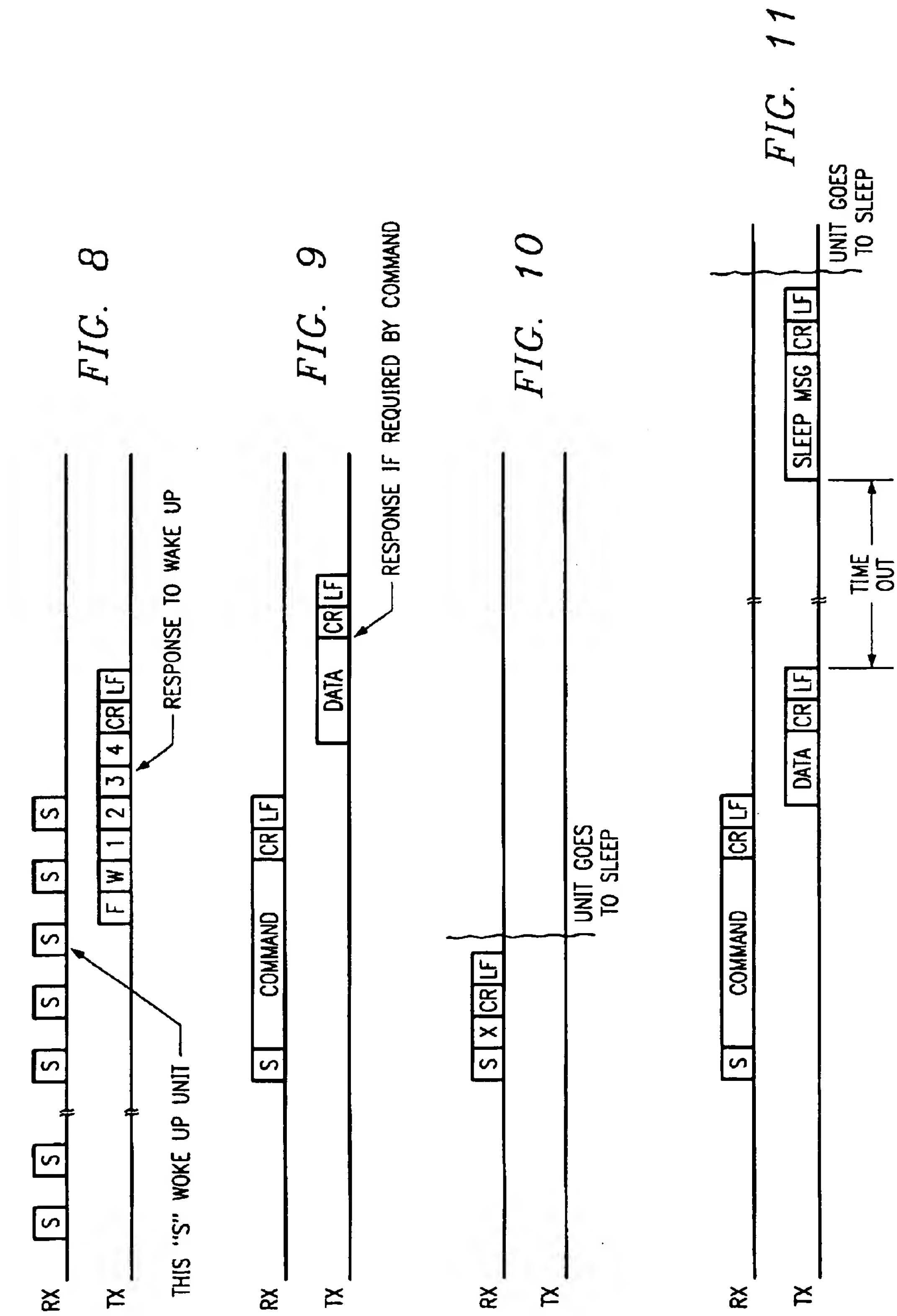


FIG. 8

FIG. 9

FIG. 10

FIG. 11

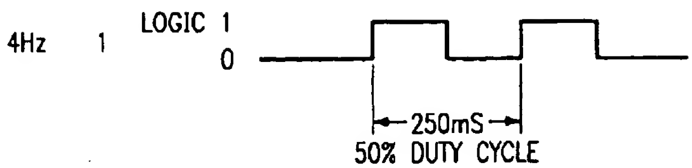


FIG. 12

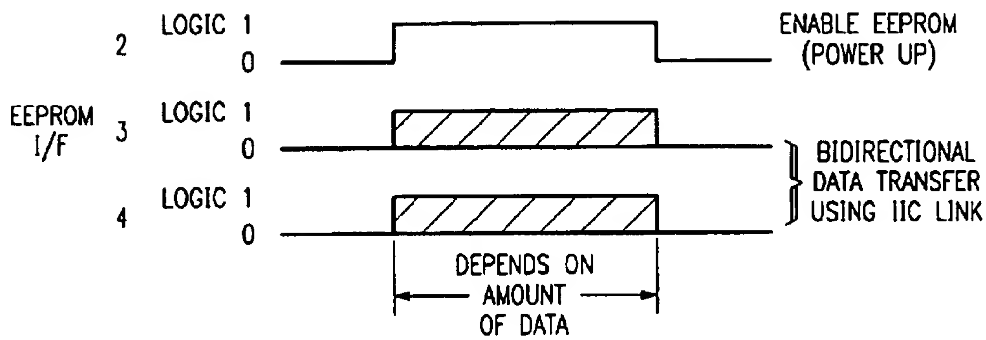


FIG. 13

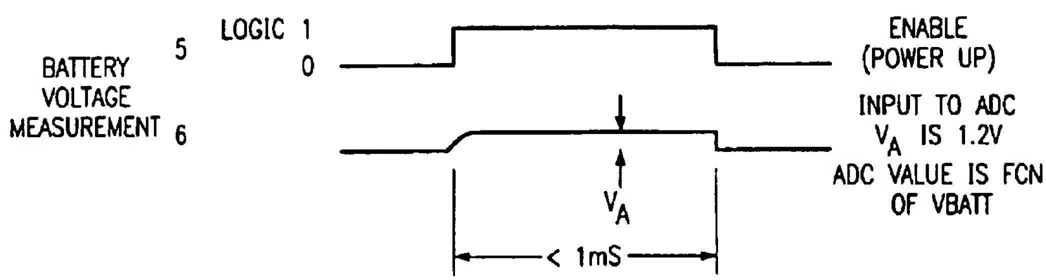


FIG. 14

FIG. 15A

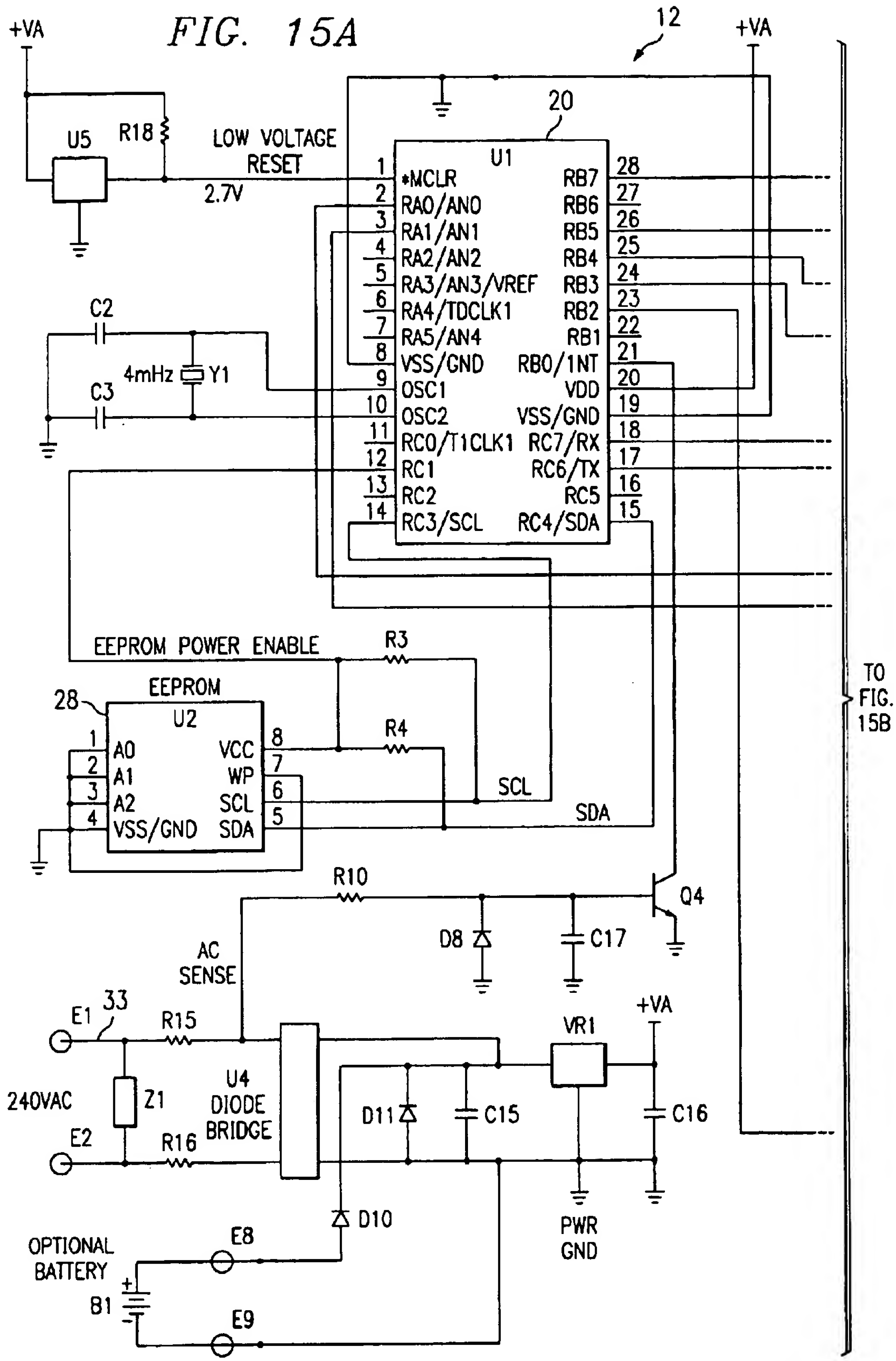
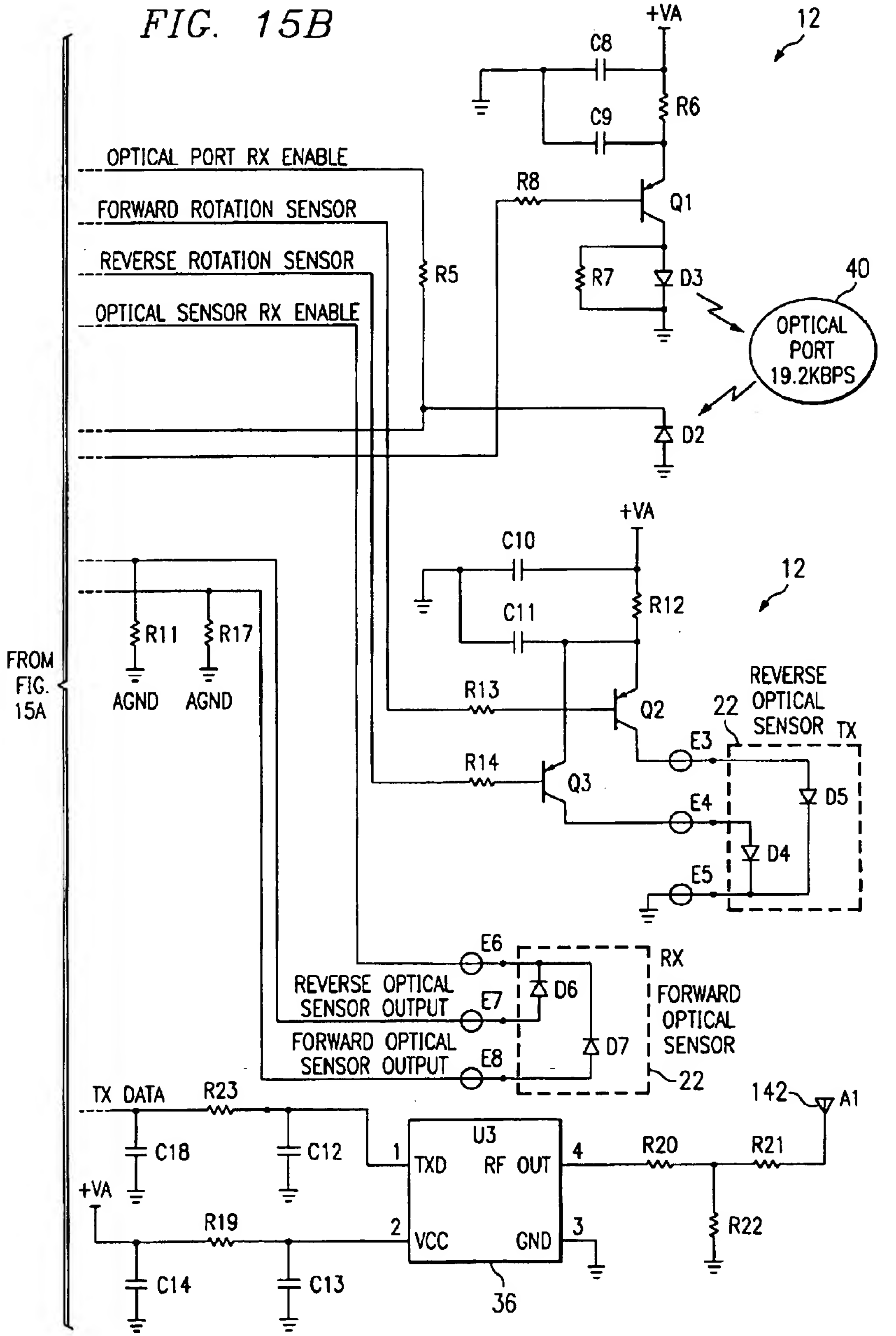

+VA
12
+VA
20
U5
R18
LOW VOLTAGE
RESET
2.7V
U1
*MCLR
RA0/AN0
RA1/AN1
RA2/AN2
RA3/AN3/VREF
RA4/TOCLK1
RA5/AN4
VSS/GND
OSC1
OSC2
RC0/T1CLK1
RC1
RC2
RC3/SCL
RB7
RB6
RB5
RB4
RB3
RB2
RB1
RB0/1NT
VDD
VSS/GND
RC7/RX
RC6/TX
RC5
RC4/SDA
C2
4mHz
Y1
C3
EEPROM POWER ENABLE
R3
EEPROM
28
U2
A0
A1
A2
VSS/GND
VCC
WP
SCL
SDA
R4
SCL
SDA
TO
FIG.
15B
R10
Q4
D8
C17
AC
SENSE
E1
33
R15
240VAC
Z1
E2
R16
U4
DIODE
BRIDGE
+VA
VR1
D11
C15
C16
D10
PWR
GND
OPTIONAL
BATTERY
E8
B1
E9

FIG. 15B


+VA
12
C8
R6
C9
OPTICAL PORT RX ENABLE
R8
Q1
FORWARD ROTATION SENSOR
REVERSE ROTATION SENSOR
R5
R7
D3
40
OPTICAL SENSOR RX ENABLE
OPTICAL PORT 19.2KBPS
D2
+VA
C10
12
R12
C11
R11
R17
FROM FIG. 15A
AGND
AGND
R13
Q2
22
REVERSE OPTICAL SENSOR
TX
E3
R14
Q3
D5
E4
D4
E5
E6
RX
D6
REVERSE OPTICAL SENSOR OUTPUT
E7
FORWARD OPTICAL SENSOR
FORWARD OPTICAL SENSOR OUTPUT
D7
E8
22
TX DATA
R23
142
A1
U3
C18
C12
1
TXD
RF OUT
4
R20
R21
+VA
R19
2
VCC
GND
3
R22
C14
C13
36

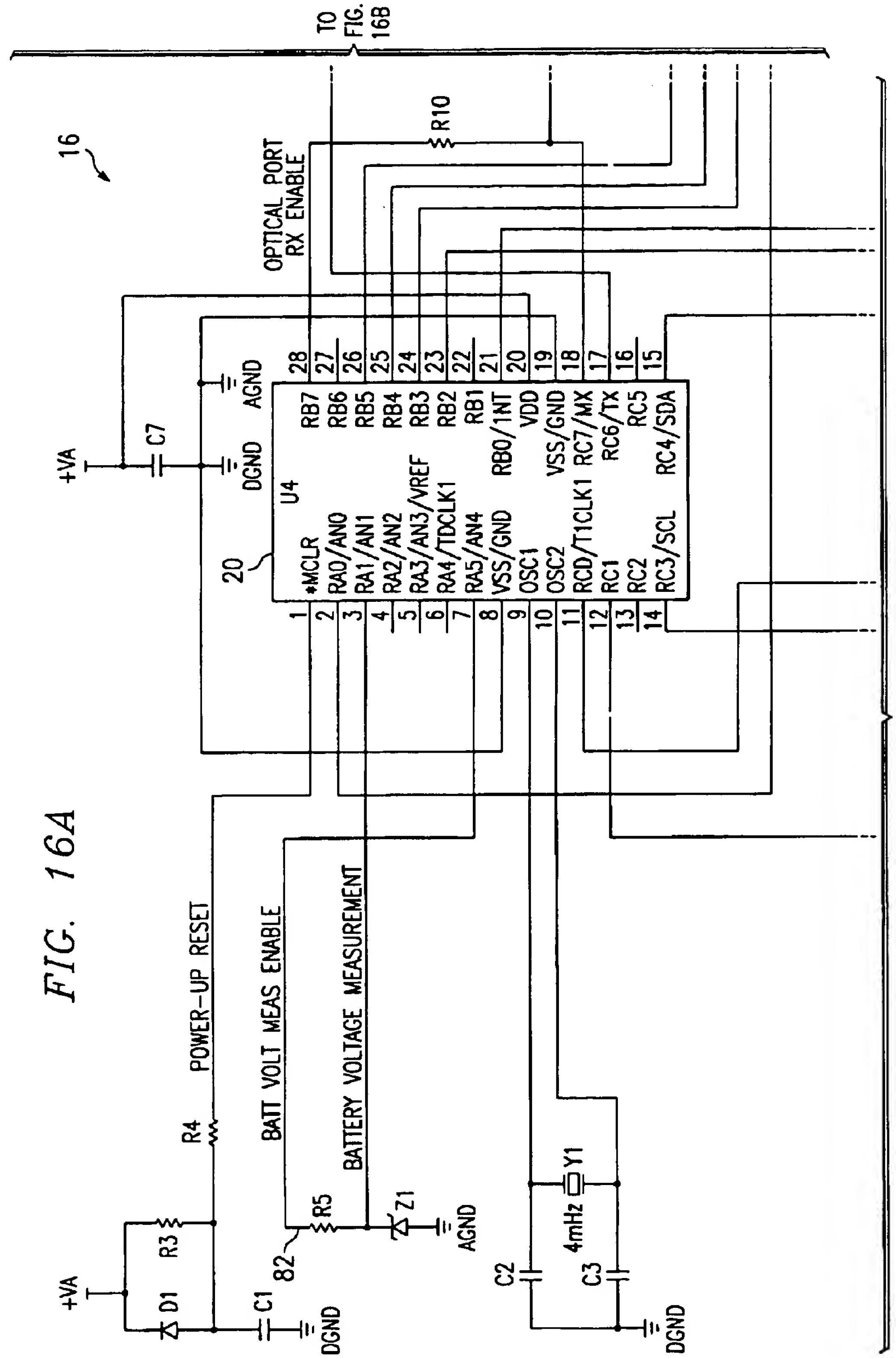
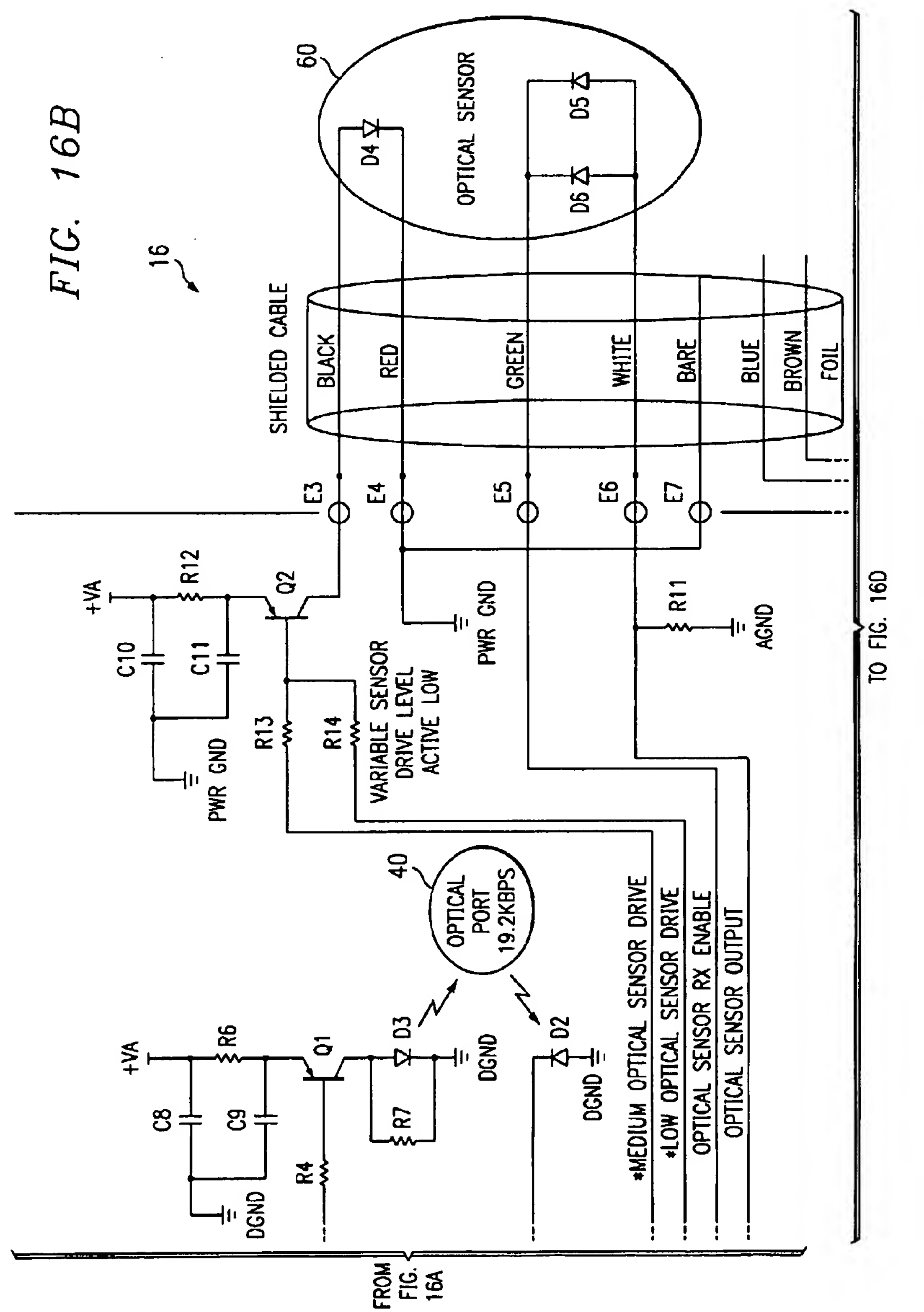

TO FIG. 16B
16
R10
OPTICAL PORT RX ENABLE
+VA
C7
DGND
AGND
U4
20
*MCLR
RA0/AN0
RA1/AN1
RA2/AN2
RA3/AN3/VREF
RA4/TOCLK1
RA5/AN4
VSS/GND
OSC1
OSC2
RCO/T1CLK1
RC1
RC2
RC3/SCL
RB7
RB6
RB5
RB4
RB3
RB2
RB1
RB0/1NT
VDD
VSS/GND
RC7/MX
RC6/TX
RC5
RC4/SDA
TO FIG. 16C
POWER-UP RESET
BATT VOLT MEAS ENABLE
BATTERY VOLTAGE MEASUREMENT
R4
R3
D1
C1
R5
82
Z1
Y1
4mHz
C2
C3

FIG. 16A

FIG. 16B


16
60
OPTICAL SENSOR
D4
D5
D6
SHIELDED CABLE
BLACK
RED
GREEN
WHITE
BARE
BLUE
BROWN
FOIL
E3
E4
E5
E6
E7
+VA
R12
Q2
C10
C11
PWR GND
R13
R14
VARIABLE SENSOR
DRIVE LEVEL
ACTIVE LOW
PWR GND
R11
AGND
TO FIG. 16D
40
OPTICAL
PORT
19.2KBPS
+VA
R6
Q1
D3
D2
C8
C9
R7
R4
DGND
DGND
DGND
*MEDIUM OPTICAL SENSOR DRIVE
*LOW OPTICAL SENSOR DRIVE
OPTICAL SENSOR RX ENABLE
OPTICAL SENSOR OUTPUT
FROM
FIG.
16A

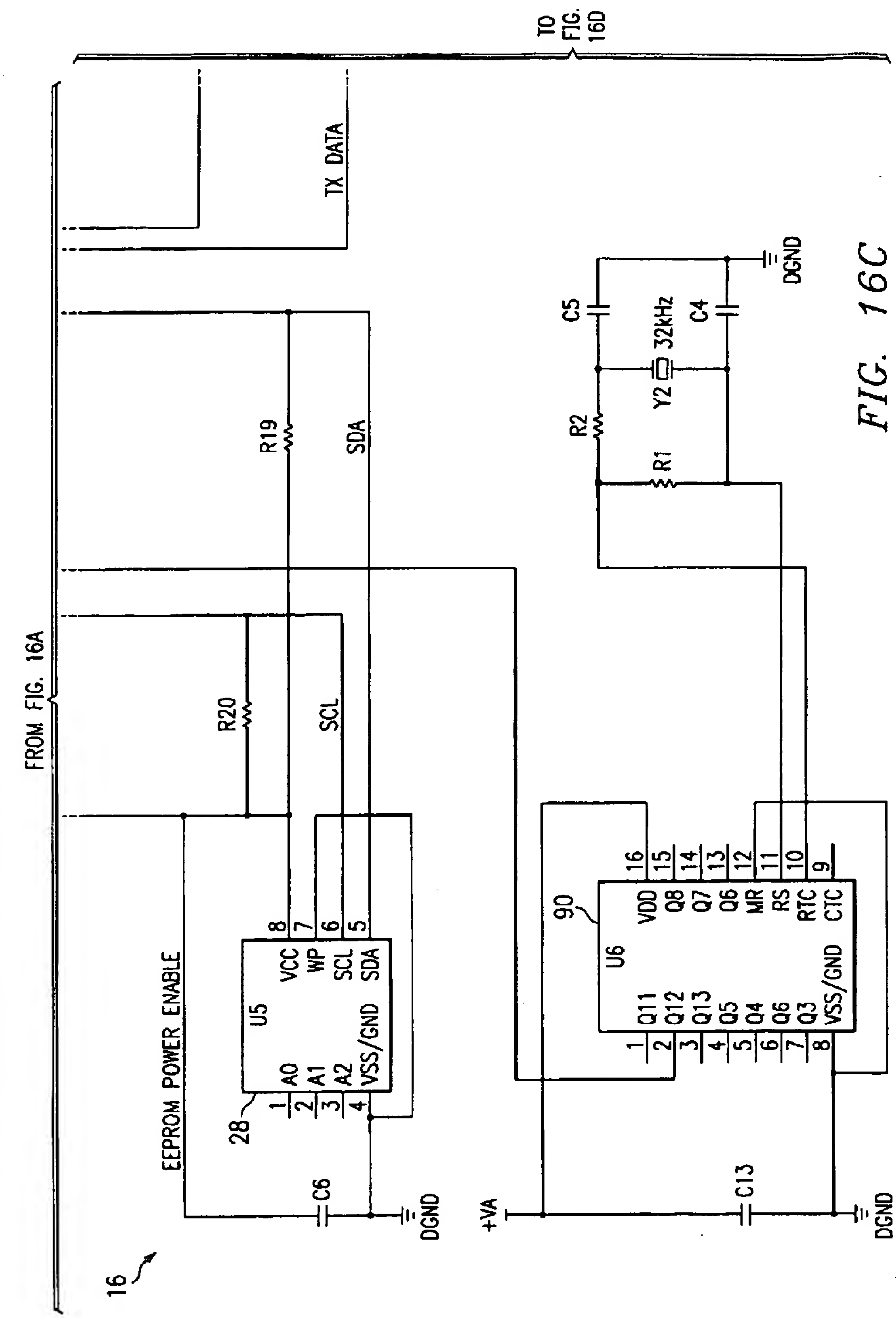

TO FIG. 16D
TX DATA
R19
SDA
R2
R1
C5
Y2
32kHz
C4
DGND
FROM FIG. 16A
R20
SCL
EEPROM POWER ENABLE
U5
VCC
WP
SCL
SDA
A0
A1
A2
VSS/GND
28
C6
DGND
+VA
C13
DGND
16
U6
90
VDD
Q8
Q7
Q6
MR
RS
RTC
CTC
Q11
Q12
Q13
Q5
Q4
Q6
Q3
VSS/GND

FIG. 16C

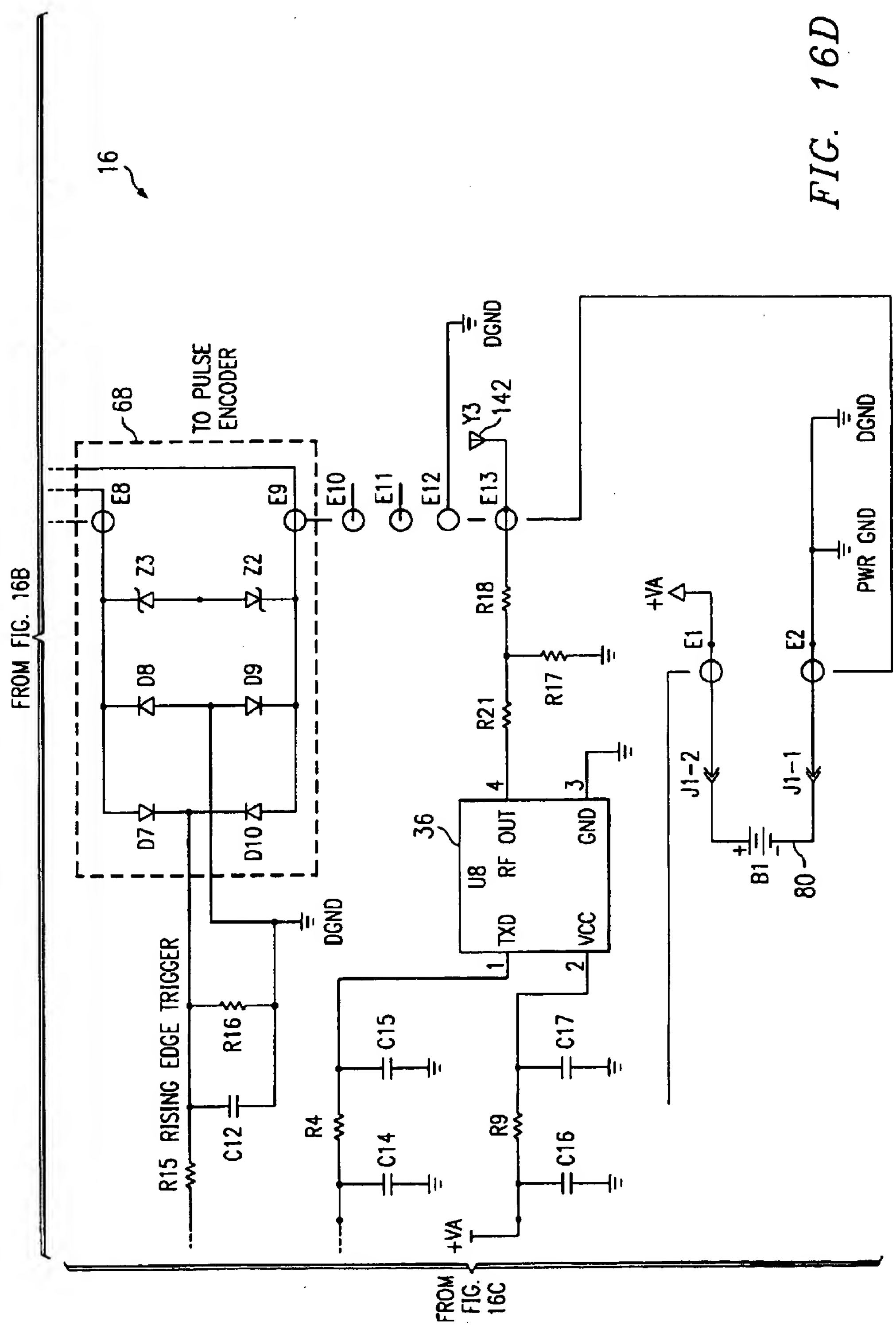

16
FROM FIG. 16B
68
TO PULSE ENCODER
E8
E9
E10
E11
E12
E13
Z3
Z2
D8
D9
D7
D10
DGND
Y3
142
R18
R17
R21
+VA
E1
E2
PWR GND
J1-2
J1-1
B1
80
36
U8
RF OUT
GND
TXD
VCC
1
2
3
4
R15 RISING EDGE TRIGGER
R16
C12
R4
C14
C15
R9
C16
C17
FROM FIG. 16C

FIG. 16D

FIG. 17A

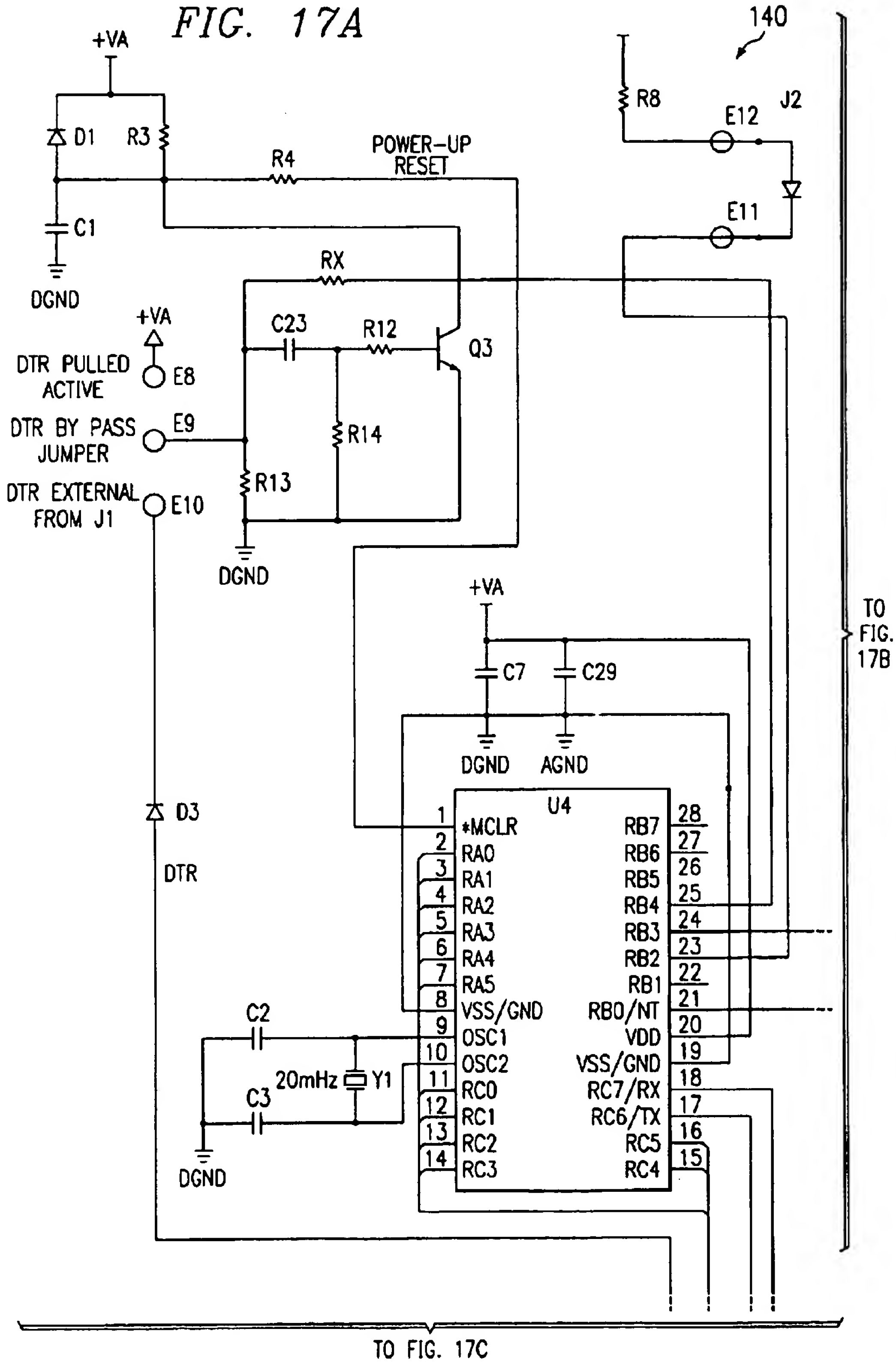
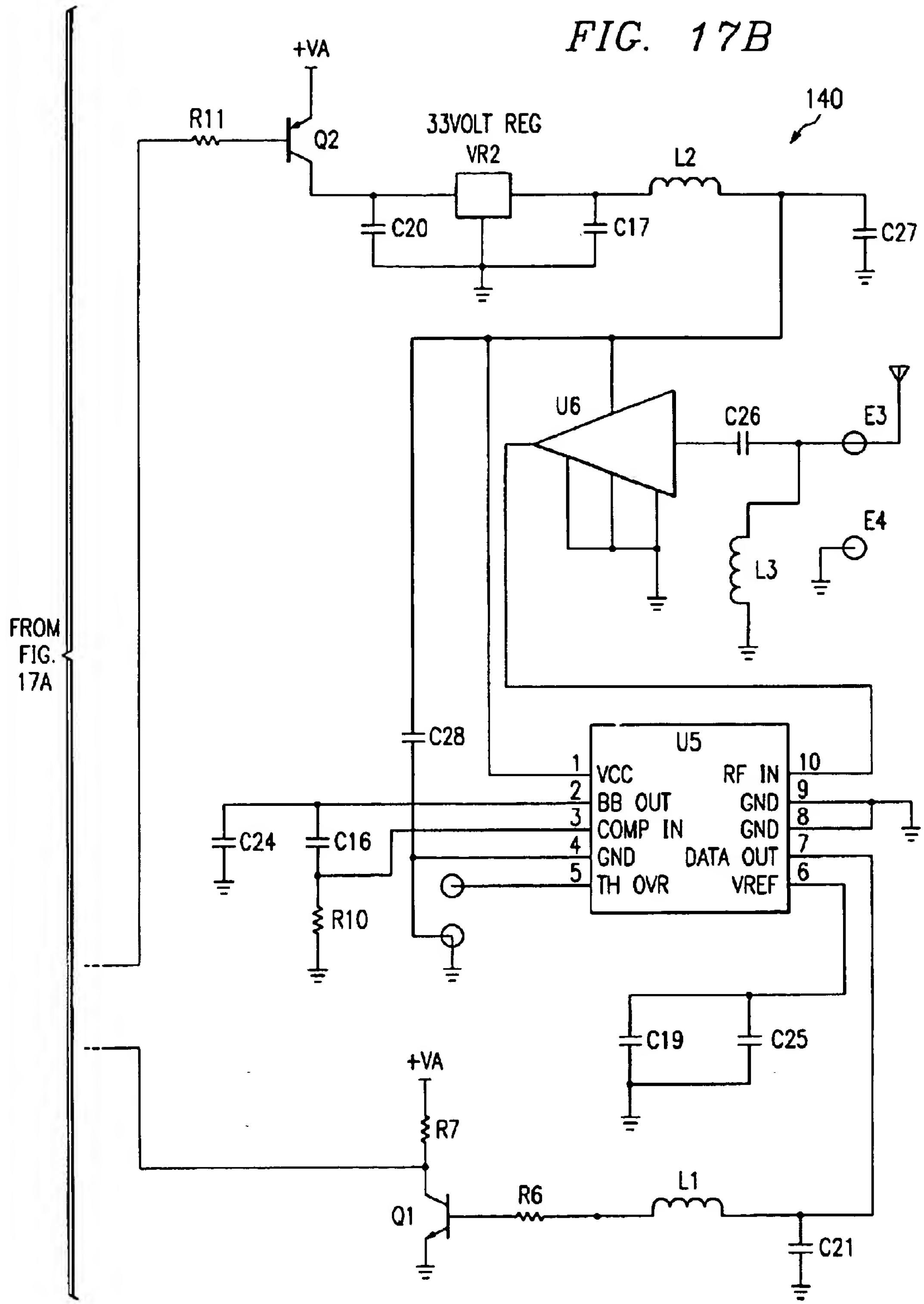

140
+VA
D1
R3
R4
POWER-UP RESET
C1
DGND
R8
E12
J2
E11
RX
+VA
C23
R12
Q3
DTR PULLED ACTIVE
E8
DTR BY PASS JUMPER
E9
R14
DTR EXTERNAL FROM J1
E10
R13
DGND
+VA
C7
C29
DGND
AGND
TO FIG. 17B
U4
D3
DTR
*MCLR
RA0
RA1
RA2
RA3
RA4
RA5
VSS/GND
OSC1
OSC2
RC0
RC1
RC2
RC3
RB7
RB6
RB5
RB4
RB3
RB2
RB1
RB0/NT
VDD
VSS/GND
RC7/RX
RC6/TX
RC5
RC4
C2
C3
20mHz
Y1
DGND
TO FIG. 17C

FIG. 17B


140
+VA
R11
Q2
33VOLT REG
VR2
L2
C20
C17
C27
U6
C26
E3
E4
L3
FROM
FIG.
17A
C28
U5
1 VCC
2 BB OUT
3 COMP IN
4 GND
5 TH OVR
RF IN 10
GND 9
GND 8
DATA OUT 7
VREF 6
C24
C16
R10
C19
C25
+VA
R7
Q1
R6
L1
C21

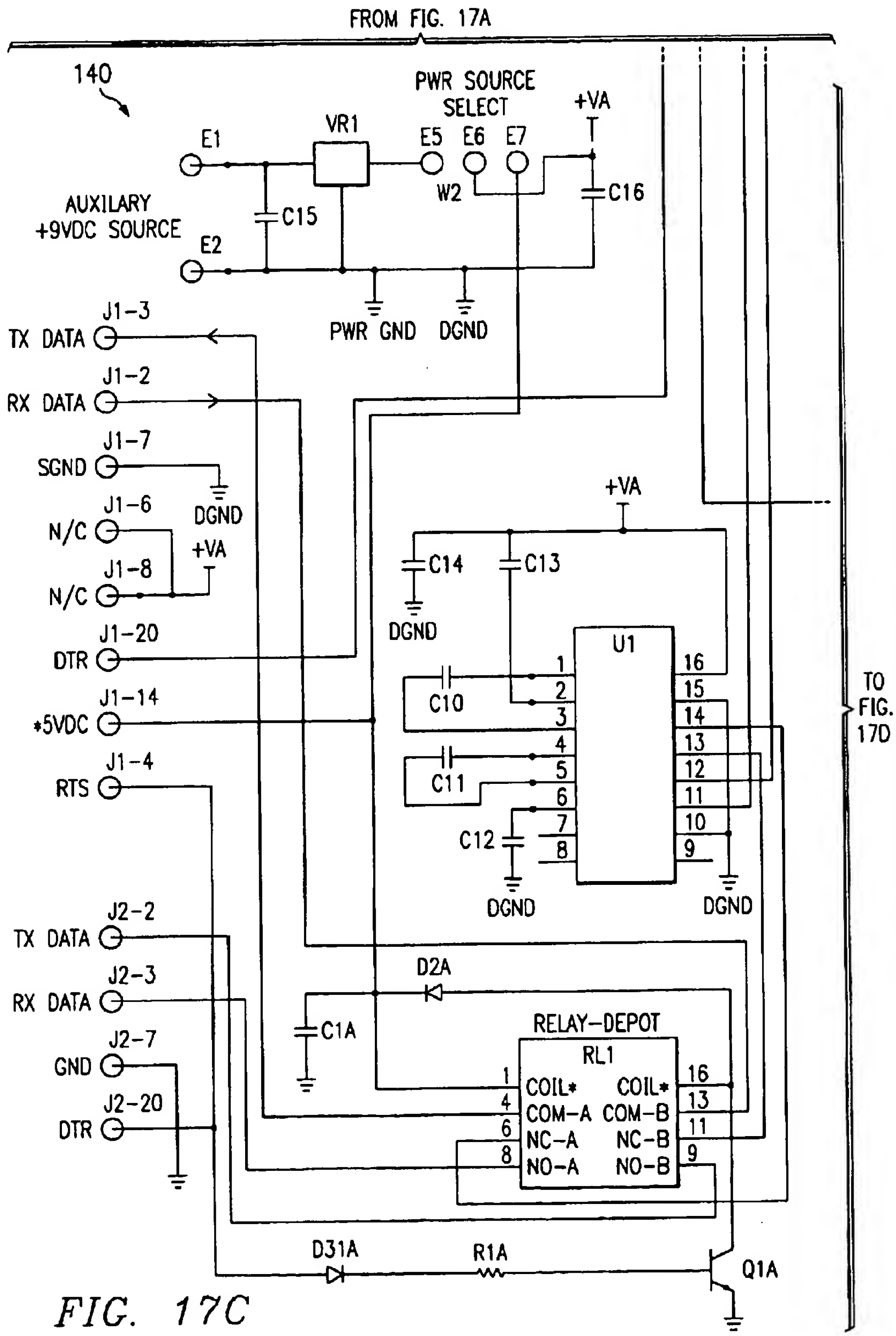
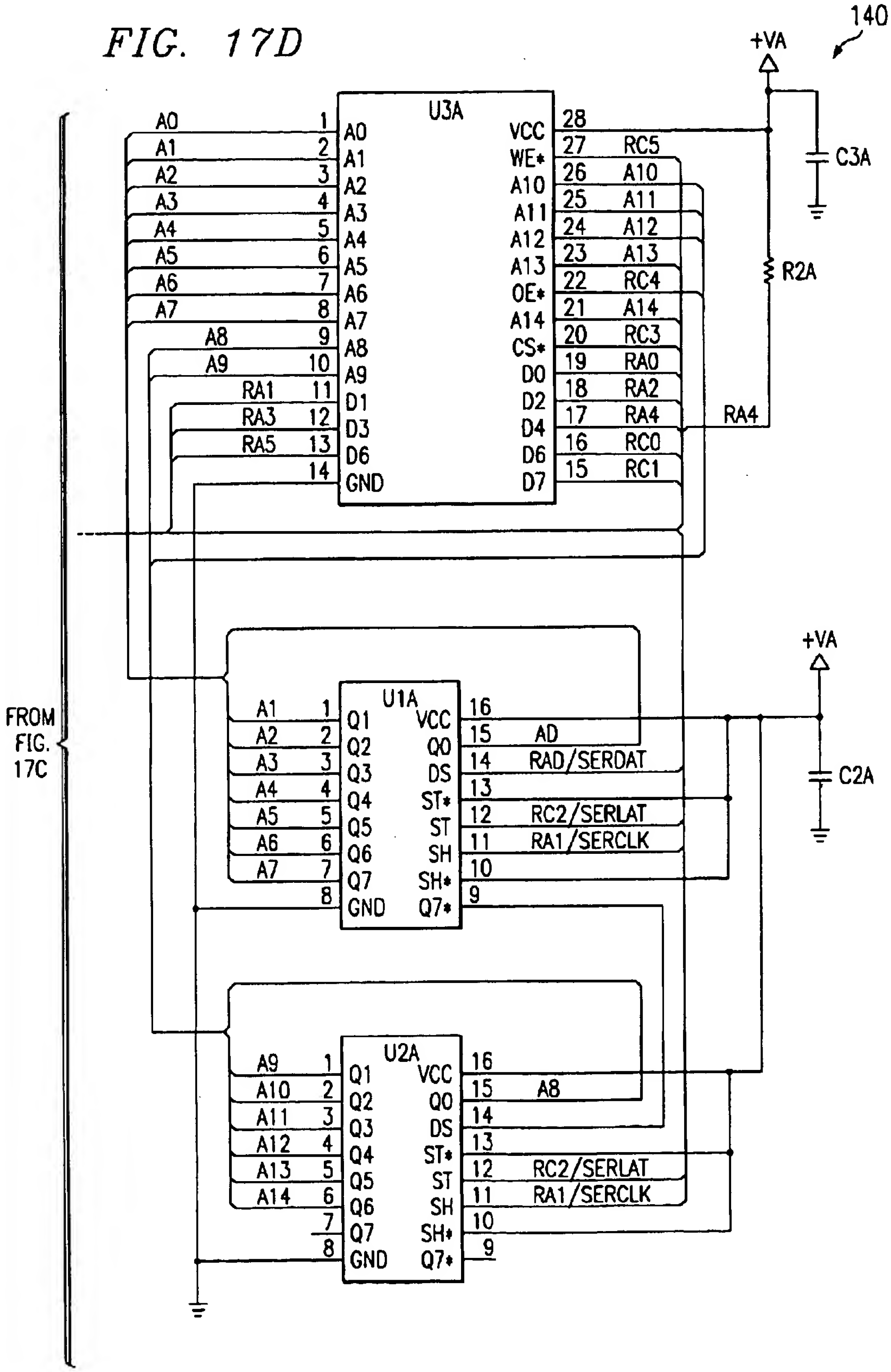

FROM FIG. 17A
140
PWR SOURCE SELECT
+VA
E1
VR1
E5 E6 E7
W2
C16
AUXILARY +9VDC SOURCE
C15
E2
PWR GND DGND
J1-3
TX DATA
J1-2
RX DATA
J1-7
SGND
J1-6
DGND
N/C
+VA
J1-8
N/C
J1-20
DTR
J1-14
*5VDC
J1-4
RTS
+VA
C14
C13
DGND
U1
C10
C11
C12
DGND
DGND
J2-2
TX DATA
J2-3
RX DATA
J2-7
GND
J2-20
DTR
D2A
C1A
RELAY-DEPOT
RL1
COIL* COIL*
COM-A COM-B
NC-A NC-B
NO-A NO-B
D31A
R1A
Q1A
TO FIG. 17D

FIG. 17C

FIG. 17D



140
+VA
U3A
A0
A1
A2
A3
A4
A5
A6
A7
A8
A9
D1
D3
D6
GND
VCC
WE*
A10
A11
A12
A13
OE*
A14
CS*
D0
D2
D4
D6
D7
RC5
A10
A11
A12
A13
RC4
A14
RC3
RA0
RA2
RA4
RC0
RC1
RA1
RA3
RA5
C3A
R2A
RA4
FROM FIG. 17C
+VA
U1A
Q1
Q2
Q3
Q4
Q5
Q6
Q7
GND
VCC
Q0
DS
ST*
ST
SH
SH*
Q7*
AD
RAD/SERDAT
RC2/SERLAT
RA1/SERCLK
C2A
U2A
A9
A10
A11
A12
A13
A14
A8
RC2/SERLAT
RA1/SERCLK

RADIO FREQUENCY AUTOMATED METER READING DEVICE

FIELD OF THE INVENTION

The present invention is generally related to utility meter reading devices, and more particularly to automated devices utilized to remotely and efficiently obtain meter readings of utility meters providing electric, gas and water service.

BACKGROUND OF THE INVENTION

Organizations which provide electric, gas and water service to users are commonly referred to as "utilities". Utilities determine charges and hence billings to their customers by applying rates to quantities of the service that the customer uses during a predetermined time period, generally a month. This monthly usage is determined by reading the consumption meter located at the service point (usually located at the point where the utility service line enters the customer's house, store or plant) at the beginning and ending of the usage month. The numerical difference between these meter readings reveals the kilowatts of electricity, cubic feet of natural gas, or the gallons of water used during the month. Utilities correctly perceive these meters as their "cash registers" and they spend a lot of time and money obtaining meter reading information.

An accepted method for obtaining these monthly readings entails using a person (meter reader) in the field who is equipped with a rugged hand held computer, who visually reads the dial of the meter and enters the meter reading into the hand held. This method, which is often referred to as "electronic meter reading", or EMR, was first introduced in 1981 and is used extensively today. While EMR products today are reliable and cost efficient compared to other methods where the meter reader records the meter readings on paper forms, they still necessitate a significant force of meter readers walking from meter to meter in the field and physically reading the dial of each meter.

The objective of reducing the meter reading field force or eliminating it all together has given rise to the development of "automated meter reading", or AMR products. The technologies currently employed by numerous companies to obtain meter information are:

Radio frequency (RF)

Telephone

Coaxial cable

Power line carrier ("PLC")

All AMR technologies employ a device attached to the meter, retrofitted inside the meter or built into/onto the meter. This device is commonly referred to in the meter reading industry as the Meter Interface Unit, or MIU. Many of the MIU's of these competing products are transceivers which receive a "wake up" polling signal or a request for their meter information from a transceiver mounted in a passing vehicle or carried by the meter reader, known as a mobile data collection unit ("MDCU"). The MIU then responsively broadcasts the meter number, the meter reading, and other information to the MDCU. After obtaining all the meter information required, the meter reader attaches the MDCU to a modem line or directly connects it to the utility's computer system to convey the meter information to a central billing location. Usually these "drive by" or "walk by" AMR products operate under Part 15 of the FCC Rules, primarily because of the scarcity of, or the expense of obtaining, licenses to the RF spectrum. While

these types of AMR systems do not eliminate the field force of meter readers, they do increase the efficiency of their data collection effort and, consequentially, fewer meter readers are required to collect the data.

Some AMR systems which use RF eliminate the field force entirely by using a network of RF devices that function in a cellular, or fixed point, fashion. That is, these fixed point systems use communication concentrators to collect, store and forward data to the utilities central processing facility. While the communication link between the MIU and the concentrator is almost always either RF under Part 15 or PLC, the communication link between the concentrator and the central processing facility can be telephone line, licensed RF, cable, fiber optic, public carrier RF (CDPD, PCS) or LEO satellite RF. The advantage of using RF or PLC for the "last mile" of the communication network is that it is not dependent on telephone lines and tariffs.

There is desired an improved meter reading device and methodology which improves upon the available AMR products through simplification and ease of use.

SUMMARY OF THE INVENTION

The present invention achieves technical advantages as an AMR device and method of use which is adapted to couple to utility meters to obtain data including a measured quantity of delivered product, and further including control circuitry and a transmitter generating a data signal indicative of the measured quantity at a particular RF frequency and predetermined time interval, without requiring external polling. The control circuitry generates the data signal periodically at a first predetermined time interval which can be selectively programmed via a programming module by a separate programming or diagnostic device. The present invention achieves technical advantages by not requiring external polling to obtain data, thereby simplifying the data collection process by eliminating complicated data exchange protocols and simplifying the equipment required (i.e. using a transmitter at the MIU instead of a transceiver).

The present invention comprises a device having an interface module adapted to couple to a utility meter measuring a quantity of a delivered product, the interface module providing a first signal indicative of the measured quantity. The device further comprises a controller receiving the first signal and generating a data signal indicative of the measured quantity at a first predetermined time interval, without requiring external polling. A transmitter responsively coupled to the controller circuit modulates the data signal, and transmits the modulated data signal at a predetermined RF frequency. Preferably, the controller formats the data signal into a data stream having a plurality of fields. A first field comprises data indicative of the measured quantity of delivered product, i.e. meter reading. Another second field comprises data indicative of an identity of the measuring unit. The device is particularly adapted to obtain the measured quantity of delivered product comprising of electricity, natural gas and water, and can be adapted to other meters delivering product as well.

The present invention further comprises a programming module functionally coupled to the controller and adapted to selectively adjust operating parameters of the controller. The programming module is adapted to selectively adjust, for instance, the predetermined time interval between transmissions of the modulated data signal, for instance, allowing the data to be selectively transmitted ever 10 seconds, ever minute, once an hour, and so forth. The programming module comprises a transceiver adapted to provide data to a diagnostic and programming device indicative of operating

characteristics of the device, including any changes of device performance, battery levels, and further allowing the reception of data such as to update of internal software via downloading through the transceiver when desired. The interface module preferably comprises an optical sensor and optical transmitter, such as an Infrared (IR) transceiver.

According to a second embodiment of the present invention, there is provided a method of transmitting a data signal comprising the steps of sensing a utility meter measuring a quantity of a delivered product, and responsively generating a first signal indicative of the sensed measured quantity. The data signal is formatted and has a plurality of fields, wherein a first field is indicative of the sensed measured quantity of product. This formatted data signal is modulated and transmitted as a modulated data signal at a predetermined RF frequency. This modulated data signal is preferably transmitted at a predetermined time interval, and advantageously does not require any external polling signal, complicated data exchange protocols, or complicated data exchange algorithms. The method of the present invention further provides the step of adjusting the format of the first signal using a programming device, wherein the programming device comprises an IR transceiver. The measured product may comprise of water, electricity, gas, or other consumed product of a household.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a perspective view of a data transmitting module according to the present invention adapted to a household electric meter;

FIG. **2** is a perspective view of a data transmitting device according to a second embodiment of the present invention adapted to be fastened onto a water meter pit lid and adapted to read a water meter;

FIG. **3** is a electrical block diagram of an electric meter unit according to the first embodiment of the present invention;

FIG. **4** is an electrical block diagram of a water meter unit according to a second embodiment of the present invention;

FIG. **5** is a signal timing diagram of the optical sensor unit for the electric meter of FIG. **3**;

FIG. **6** is a signal timing diagram of the optical sensor of the water meter unit of FIG. **4**;

FIG. **7** is a byte data format diagram for the water and electric meter units;

FIG. **8** is a timing diagram of an initiated wake-up sequence by a remote programming device;

FIG. **9** is a timing diagram of a command/response sequence of the controller to the remote programming device;

FIG. **10** is a timing diagram of a sleep command being provided to the controller;

FIG. **11** is a sleep timing diagram of sequence;

FIG. **12** is a timing diagram of an oscillator of the water meter unit;

FIG. **13** is a timing diagram of the controller communicating with the EE PROM of the water and electric units;

FIG. **14** is a timing diagram of the controller of the water unit measuring interval battery voltages;

FIG. **15** is a full electrical schematic of the electric meter unit according to the first preferred embodiment of the present invention;

FIG. **16** is a full electrical schematic of the water meter unit according to the second embodiment of the present invention; and

FIG. **17** is a full schematic diagram of a receiver adapted to receive and process modulated data signals from the data transmitting devices according to the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to FIG. **1**, there is illustrated a household electric meter unit generally shown at **10** having adapted therewith an electric meter reading unit **12** according to a first preferred embodiment of the present invention coupled to sense a black spot **13** on the rotating meter disk generally shown at **14**. Electric meter unit **12** has an optical sensor for detecting the passing of the back spot **13** there past to ascertain the consumed amount of electricity correlated to the read out of the visual display **15** of meter unit **10**.

FIG. **2** is the perspective view of a water meter unit according to a second preferred embodiment of the present invention generally being shown at **16**. The circular structure **18** on the top of device **16** is adapted to fasten the unit **16** onto a water meter pit lid (not shown) with an antenna node (not shown) sticking up through a hold drilled through the pit lid.

Referring now to FIG. **3**, there is illustrated an electrical block diagram of the electric meter unit **12** according to the first embodiment of the present invention. Electric meter unit **12** is seen to include a controller **20**, which may comprise of a microcontroller, a digital signal processor (DSP) or other suitable controlling device, preferably being a programmable integrated circuit having suitable software proramming. Device **12** is further seen to include an infrared (IR) optical sensor **22** adapted to sense the passing of the black spot **13** of the metered disk **14** of electric meter unit **10**. Optical sensor **22** preferably operates by generating pulses of light using a light emitting diode, and sensing the reflection of light from the meter disk **14**, and determining the passing of the black spot **13** by sensing a reduced reflection of the impinging light therefrom.

Electric meter unit **12** is further seen to include a memory device comprising an EE PROM **28** storing operating parameters and control information for use by controller **20**. An AC sense module **30** is also coupled to controller **20** and senses the presence of AC power **33** being provided to the meter unit **10** via an AC interface **32**.

A radio frequency (RF) transmitter **36** is coupled to and controlled by controller **20**, and modulates a formatted data signal provided thereto on line **38**. RF transmitter **36** modulates the formatted data signal provided thereto, preferably transmitting the modulated signal at a frequency of about 916.5 MHz at 9600 bits per second (BPS), although other frequencies or data rates are suitable and limitation to this frequency or baud rate is not to be inferred.

A programming optical port **40** is provided and coupled to controller **20** which permits communication between controller **20** and an external optical infrared device **42** used for programming controller **20**, and for selectively diagnosing the operation of electric meter unit **12** via the optical port **40**. Optical port **40** has an IR transceiver adapted to transmit and receive infrared signals to and from the external device **42** when the external device **42** is disposed proximate the optical port **40** for communication therewith. Device **42** asynchronously communicates with controller in a bidirectional manner via port **40**, preferably at 19,200 baud.

Optical sensor **22** communicates via a plurality of signals with controller **20**. Optical sensor **22** provides analog voltages indicative of and corresponding to the sensed black spot of disk **24** via a pair of data lines **50** and **52** which

interface with an analog to digital controller (ADC) **54** forming a sub-portion of controller **20**.

Referring now to FIG. **4**, there is generally shown detailed electrical block diagram of the water meter unit **16** according to the second preferred embodiment of the present invention, wherein like numerals refer to like elements to those shown in FIG. **3**. The water meter unit **16** is substantially similar to the electric meter unit **12** in function, but having some differences necessary for operation with a household water meter unit. Specifically, water meter unit **16** has an optical sensor **60** adapted to be positioned proximate a water meter face **62** having a needle **64**, which needle **64** indicates a consumed amount of water communicated through the water meter unit. Optical sensor **60** senses the position of needle **64** via infrared (IR) sensing electronics, and provides the sensed position of needle **64** via communication link **66** to an optical sensor interface **68**. The sensed position of needle **64** is provided as a data signal comprising an analog voltage transmitted on line **70** to an ADC **72** of controller **20**. In this embodiment, water meter unit **16** is provided with an internal battery **80** powering the microcontroller **20** and other circuitry, preferably being a lithium battery operating at about 3.6 volts. A battery voltage measuring unit **82** senses and measures the current operating voltage of battery **80**, and outputs an analog voltage signal indicative thereof on line **84** to an ADC **86** of microcontroller **20**. The value of the analog voltage signal on line **84** is a function of the battery voltage of battery **80** and is about 1.2 volts when battery **80** is providing 3.6 volts. The value of the Battery Voltage Measuring circuit is about 1.2V, but the perceived value by the ADC is a function of the ADC Ref voltage, which is the battery voltage. For example, if the ADC measures the 1.2V and it was 33% full scale of the ref voltage (battery voltage), then the battery voltage would be:

$1.2 \times 1/0.33 = 3.6V$ The 1.2V is constant over a wide battery voltage range.

A low power oscillator **90** operating at about 32 kHz generates a 4 Hz logic interrupt signal to controller **20**, which controls the speed of controller **20**. By providing only a 4 Hz interrupt signal, microcontroller **20** operates at a very slow speed, and thus consumes very little power allowing water meter unit **16** to operate at up to about 10 years without requiring replacement of lithium battery **80**.

The EE PROM **28** is selectively enabled by the microcontroller **20** via an enable line **96**, and once enabled, communication between the microcontroller **20** and the EE PROM **28** follows an IIC protocol. Likewise, the battery voltage measuring device **82** is selectively enabled powered by the microcontroller **20** via a control line **98** such that the battery voltage is sensed only periodically by the controller **20** to conserve power.

The optical sensor **60** is controlled by controller **20** via optical sensor interface **68** to determine the water position and presence of meter needle **64**. The sensor **60** is attached to the lens of the water meter (not shown). An infrared (IR) signal **100** is periodically transmitted from the sensor **60**, and the reflection of the IR signal is measured by the sensor **60** to determine the passage of needle **64**. The sensor **60** operates in cyclic nature where the sensing is performed every 250 milliseconds. The intensity of the IR signal transmitted by sensor **60** is controlled by two drivelines on control line **66** from the micro-controller **20**. The IR intensity is set according to the optical characteristics of the water meter face. The sensor **60** emits an intense, but short burst of IR light. The IR receiver **68** responsively generates an analog voltage on signal line **70** which voltage is a function of the received IR light intensity from optical sensor **60**. This voltage is connected directly to the ADC **72** of the controller **20**. The controller **20** measures this converted (digital) signal, and uses the value in an algorithm that ascertains the value over time to determine if the water meter needle has passed under the sensor **60**. The algorithm also compensates for the effects of stray light. The mechanical shape of the sensor **60** and orientation of the IR devices, such as light emitting diodes, determines the optical performance of the sensor and its immunity to stray IR light.

The water meter unit **16** periodically transmits a modulated formatted data signal on an RF link **110** that is preferably tuned at 916.5 MHz with on-off-keyed data at 9600 bits per second (9600 baud). The transmitter **36** transmits the data in formatted packets or messages, as will be discussed shortly. These formatted messages are transmitted at a repetition rate that has been initialized into the unit **16**, and which may be selectively set between every one second and up to intervals of every 18 hours, and which may be changed via the optical port **40** by the programminge external optical device **42**. The formatted messages modulated by the transmitter **36**, as will be discussed shortly, contain fields including an opening flag, message length, system number, message type, data, check sum and closing flag, as will be discussed shortly in reference to FIG. **7**. The messages are variable length, whereby the message length field indicates how long the message is. The message type field indicates how to parse or decode the data field. Different messages carry and combine different data items. Data items include network ID, cumulative meter reading, clock time, battery voltage, sensor tamper, sensor diagnostic, and trickle flags.

As previously mentioned, low power 32 kHz oscillator **90** generates a 4 Hz square wave output. This signal is connected to the controller **20** which causes an interrupt ever 250 milliseconds. The micro-controller uses this interrupt for clock and timing functions. In normal mode, the microcontroller is asleep and wakes up every 200 milliseconds and performs a scheduling task for about 50 milliseconds. If a task is scheduled to execute, it will execute that task and return to sleep. In normal mode, all tasks are executed within the 250 millisecond window.

In the case of the optical sensor **22** of FIG. **3**, the sensor **22** is attached to the electric meter such that the sensor faces the metered disk surface. The IR signal is periodically transmitted from the sensor and the reflection is measured. As the black spot passes under the sensor, a variation in the reflected IR signal occurs. The sensor operates in cyclic nature where the sensing is performed every 33 milliseconds. The IR receiver of sensor **22** generates analog voltages on lines **50** and **52** that is a function of the received IR light intensity and are connected to the ADC **72** in the microcontroller **20**. The controller **20** measures this converted (digitized) voltage, and used the value in the algorithm. The algorithm senses the values over time to determine if the black spot has passed under the sensor. To detect reverse rotation of the metered disk, the sensor **22** has two sensors, as shown. The controller **22**, with its algorithm, determines the direction of disk rotation as the black spot passes the sensor **22**. The black spot is a decal and does not reflect IR light. This is determined by the decal's material, color and surface texture. As with the water meter, the algorithm and sensor shrouding compensate for the effects of stray light.

The AC line interface **32** interfaces to the AC line coupled to the electric meter through a resistive tap. The resistors limit the current draw from the AC line to the electric meter unit **12**. The AC is then rectified and regulated to power the unit **12**. The AC sensor **30** detects the presence of AC

voltage on the AC line **33**. The sensed AC is rectified and a pulse is generated by sensor **30**. This pulse is provided to the micro-controller **20** where it is processed to determine the presence of adequate AC power.

Referring now to FIG. **5**, there is shown a waveform diagram of the signals exchanged between the optical sensor **22** and the controller **20** of the electric meter unit **12** shown in FIG. **3**. The logic signals generated by controller **20** control the optical sensor **22** to responsively generate an IR signal and sense a refracted IR signal from the metered disk **24**. It can be seen that the reflected 0.3 millisecond IR signal is acquired within 1.3 milliseconds after enabling for sensing by ADC **54** and processed by controller **20**. Preferably, this measuring sequence is performed every 33 milliseconds, which periodic rate can be programmed via optical port **40** if desired.

Referring now to FIG. **6**, there is shown the timing diagram of the signals between optical sensor **68** and controller **20** for water meter unit **16** of FIG. **4**. The logic of the driving signals is shown below in Table 1.

TABLE 1

Net Sensor Drive	Drive 1	Drive 2
High	0	0
Medium	0	1
Low	1	0

As shown in the timing diagram of FIG. **6**, the analog signal provided on line **70** by optical sensor **68** rises to an accurate readable voltage in about 140 milliseconds, and has a signal width of about 270 milliseconds. The period of the analog voltage is about 250 milliseconds, corresponding to a signal acquisition rate of 4 Hz corresponding to the timing frequency provided on line **92** to controller **20**.

Referring now to FIG. **7**, there is shown the message format of the data signal provided by controller **20** on output line **38** to RF transmitter **36**. The message is generally shown at **120** and is seen to have several fields including:

opening flag (OF) comprised of two bytes;

message length (ML) having a length of one byte;

system number (SN) having a length of one byte;

message type (MT) one byte;

data, which length is identified by the message length parameter (ML);

check sum (CSUM) two bytes; and

closing flag (CF) one byte.

Further seen is the data format of one byte of data having one start bit and 8 bits of data non-returned to zero (NRZ) and one stop-bit. The length of each byte is preferably 1.04 milliseconds in length.

Referring now to FIG. **8**, there is illustrated the message format and timing sequence of messages generated between the external optical timing device **42** and microcontroller **20** via optical port **40**. As shown in FIG. **8**, a plurality of synchronization bytes are provided by device **42** on the receive data (RXD) line to controller **20**, and upon the recognition of the several bytes by controller **20**, the controller **20** generates a response message to the wake-up message on the transmit data (TXD) line via optical port **40** to the external device **42**. Thereafter, shown in FIG. **9**, a command data message may be provided by the external device **42** to controller **20** on receive data line RXD, with response data, if required, being responsively returned on the transmit data line TXD to device **42** if required by the command.

As shown in FIG. **10**, a sleep command is then generated by external device **42** upon which no response by controller **20** is generated and the unit **12** goes to sleep. As shown in FIG. **11**, after a command has been sent to controller **20**, and responded to, the unit **12** will time out after a predetermined period of time if no other commands are received, such as 120 seconds, with a message being sent by controller **20** on transmit line TXD indicating to the external device **42** that the unit **12** has gone to sleep.

The message sequence shown in FIGS. **8–11** applies equally to both the electric unit **12** and the water unit **16**. Referring now to FIG. **12**, there is illustrated the 4 Hz square wave interrupt signal generated by the low power oscillator **90** to the microcontroller **20**.

Referring to FIG. **13**, there is illustrated the timing of communications between the EE PROM **28** and the controller **20**, whereby the EE PROM is enabled by a logic one signal on line **96**, with bidirectional data being transferred using an IIC link on lines SCL, and lines SDA. This applies to both the water unit **16** and the electric unit **12**.

Referring to FIG. **14**, there is illustrated the timing diagram for sensing the internal battery voltage in the water meter unit **16** shown in FIG. **4**. A logic high signal is generated on enable line **98** by controller **20**, whereby the battery measuring unit **82** responsively senses the battery voltage via line **130** from DC battery **80**. Battery measuring unit **82** responsively provides an analog voltage signal on line **84** indicative of the voltage of battery **80** to the ADC **86** of controller **20**. The analog voltage provided on signal line **84** is approximately 1.2 volts when the battery **80** is at full strength, being about 3.6 volts.

Referring now to FIG. **15**, there is illustrated a detailed schematic diagram of the electric meter unit **12**, wherein like numerals shown in FIG. **3** refer to like elements.

Referring now to FIG. **16** there is illustrated a detailed schematic diagram of the water meter unit **16**, shown in FIG. **4**, wherein like numerals refer to like elements.

Referring now to FIG. **17**, there is illustrated a detailed schematic diagram of an external receiver unit adapted to receive and intelligently decode the modulated formatted data signals provided on RF carrier **110** by the RF transmitter **36**. This receiver **140** both demodulates the RF carrier, preferably operating at 916.5 MHz, at 9600 baud, and decodes the demodulated signal to ascertain the data in the fields of message **120** shown in FIG. **7**. This receiver unit **140** has memory for recording all data collected from the particular sensored units being monitored by a field operator driving or walking in close proximity to the particular measuring unit, whether it be a water meter, gas meter or electric meter, depending on the particular meter being sensed and sampled. All this data is later downloaded into remote computers for ultimate billing to the customers, by RF carrier or other communication means.

In a preferred embodiment, the RF carrier **110** is generated at about 1 milliwatt, allowing for receiver **140** to ascertain the modulated data signal at a range of about 1,000 feet depending on RF path loss. The RF transmitters **36** are low power transmitters operating in microburst fashion operating under part **15** of the FCC rules. The receiver **140** does not have transmitting capabilities. The receiver is preferably coupled to a hand held computer (not shown) carried by the utility meter reader who is walking or driving by the meter location.

In the case of the electric meter unit **12**, the device obtains electrical power to operate from the utility side of the power line to the meter and is installed within the glass globe of the meter. The main circuit board of this device doubles as a

mounting bracket and contains a number of predrilled holes to accommodate screws to attach to various threaded bosses present in most electric meters.

In the case of the water meter, electric power is derived from the internal lithium battery. The water meter unit **12** resides under the pit lid of the water meter unit, whereby the antenna **142** is adapted to stick out the top of the pit lid through a pit lid opening to facilitate effective RF transmission of the RF signal to the remote receiver **140**.

The present invention derives technical advantages by transmitting meter unit information without requiring elaborate polling methodology employed in conventional mobile data collection units. The meter units can be programmed when installed on the meter device, in the case of the water and gas meters, or when installed in the electric meter. The external programming diagnostic device **42** can communicate with the optical port **40** of the units via infrared technology, and thus eliminates a mechanical connection that would be difficult to keep clean in an outdoor environment. Also, the optical port **40** of the present invention is not subject to wear and tear like a mechanical connection, and allows communication through the glass globe of an electric meter without having to remove the meter or disassemble it. In the case of the electric meter, the present invention eliminates a potential leakage point in the electric meter unit and therefore allows a more watertight enclosure.

The transmitting meter units of the present invention can be programmed by the utility to transmit at predetermined intervals, determined and selected to be once ever second to up to several hours between transmissions. Each unit has memory **28** to accommodate the storage of usage profile data, which is defined as, a collection of meter readings at selected intervals. For example, the unit can be programmed to gather interval meter readings ever hour. If the unit is set to record interval readings every hour, the memory **28** may hold the most recent 72 days worth of interval data. This interval data constitutes the usage profile for that service point. Typically, the utility uses this information to answer customer complaints about billings and reading and as a basis for load research studies.

The profile intervals are set independently of the transmitting interval and the device does not broadcast the interval data. The only way this interval data can be retrieved by the utility is to attach the programming unit **42** to the meter unit of the present invention and download the file to a handheld or laptop computer. With the programming unit **42**, one can determine the status of the battery on the water meter which is including in the profile data.

The present invention allows one to selectively set the transmission intervals thereby controlling the battery life. The longer the interval, the longer the battery life. In the case of electric meter unit, power is derived directly from the utility side of the electric service to the meter. The battery on the water meter unit is not intended to be field replaceable. In order to control cost, the water meter product is designed to be as simple as possible with the water meter unit enclosure being factory sealed to preserve the watertight integrity of the device. Preferably, a D size lithium cell is provided, and the unit is set to transmit once every second, providing a battery life of about 10 years. The water meter unit of the present invention can be fitted to virtually any water meter in the field and the utility can reap the benefits of the present invention without having to purchase a competitor's proprietary encoder and software. In the case of existing water meters that incorporate an encoder which senses the rotation of the water meter, these encoders incorporate wire attachments points that allow attachments to the manufactures proprietary AMR device. The present invention derives advantages whereby the sensor **60** of the present invention can be eliminated, with the sensor cable **66** being coupled directly to the terminals on the encoder of this type of device.

Though the invention has been described with respect to a specific preferred embodiment, many variations and modifications will become apparent to those skilled in the art upon reading the present application. It is therefore the intention that the appended claims be interpreted as broadly as possible in view of the prior art to include all such variations and modifications.

I claim:

1. A device for connecting to a meter, comprising:
   - an interface module adapted to coupled to said meter having a rotating disk, said interface having an optical transmitter directing optical energy to the rotating disk, the interface module sensing a rotating marker on said disk and generating a first signal indicating the direction of disk rotation;
   - a controller receiving said first signal, said controller generating a data signal indicative of a measured quantity and generating profile data;
   - a wireless transmitter, responsively coupled to said controller, modulating said data signal and transmitting said modulated data signal at a fixed predetermined RF frequency at a user selectable first predetermined time interval adapted to reduce interference without requiring external polling;
   - a profile module that obtains and stores the profile data at profile time intervals being substantially longer than the first predetermined time interval, wherein the device is operable from an internal power source; and
   - an output port for outputting profile data to a reading unit.

2. The device specified in claim **1** wherein said measured product comprises electricity.

3. The device specified in claim **1** wherein said measured product comprises gas.

4. The device specified in claim **1** wherein said measured product comprises a fluid.

5. The device specified in claim **4** wherein said usage profile data is adapted to be obtained by a remote user.

6. The device specified in claim **1** wherein the device includes a module, remotely accessed by a field technician, to selectively adjust said predetermined time interval between transmissions of said modulated data signal by said transmitter.

7. The device specified in claim **1** wherein said device includes a transceiver.

8. The device specified in claim **7** wherein said transceiver is adapted to provide data to a remote field diagnostic device indicative of operating characteristics of said device.

9. The device specified in claim **8** wherein said controller is adapted to provide meter's meter number and meter reading via said transceiver.

10. The device specified in claim **8** wherein said controller is adapted to adjust a sensitivity of said interface module.

11. The device specified in claim **7** wherein said transceiver is adapted to permit polling of said controller and generate a second signal indicative of variations of said controller circuit since a prior polling.

12. The device specified in claim **1** wherein said interface module comprises an optical sensor.

13. The device specified in claim **7** wherein the transceiver comprises an IR transceiver.

* * * * *